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TEMPERATURE ERRORS OF RADIOSONDE RKZ-2 AND ITS WORKING PROCEDUR--ETC(U)
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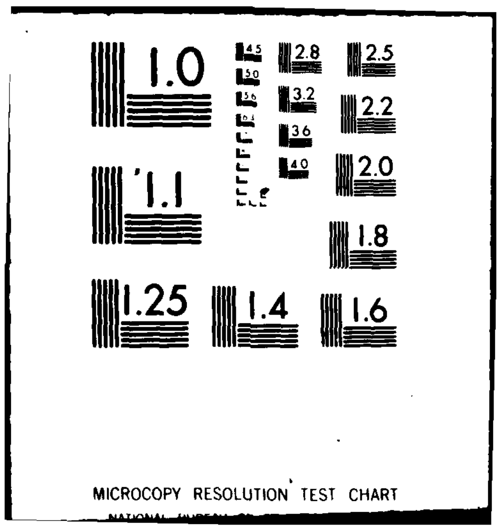
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FOREIGN TECHNOLOGY DIVISION

TEMPERATURE ERRORS OF RADIOSONDE RKZ-2 AND ITS WORKING PROCEDURE

by

O.V. Marfenko

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TEMPERATURE ERRORS OF RADIOSONDE RKZ-2 AND ITS WORKING PROCEDURE

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Block	Italic	Transliteration	Block	Italic	Transliteration
А а	*А а*	A, a	Р р	*Р р*	R, r
Б б	*Б б*	B, b	С с	*С с*	S, s
В в	*В в*	V, v	Т т	*Т т*	T, t
Г г	*Г г*	G, g	У у	*У у*	U, u
Д д	*Д д*	D, d	Ф ф	*Ф ф*	F, f
Е е	*Е е*	Ye, ye; E, e*	Х х	*Х х*	Kh, kh
Ж ж	*Ж ж*	Zh, zh	Ц ц	*Ц ц*	Ts, ts
З з	*З з*	Z, z	Ч ч	*Ч ч*	Ch, ch
И и	*И и*	I, i	Ш ш	*Ш ш*	Sh, sh
Й й	*Й й*	Y, y	Щ щ	*Щ щ*	Shch, shch
К к	*К к*	K, k	Ъ ъ	*Ъ ъ*	"
Л л	*Л л*	L, l	Ы ы	*Ы ы*	Y, y
М м	*М м*	M, m	Ь ь	*Ь ь*	'
Н н	*Н н*	N, n	Э э	*Э э*	E, e
О о	*О о*	O, o	Ю ю	*Ю ю*	Yu, yu
П п	*П п*	P, p	Я я	*Я я*	Ya, ya

*ye initially, after vowels, and after ъ, ь; e elsewhere.
When written as ё in Russian, transliterate as yё or ё.

RUSSIAN AND ENGLISH TRIGONOMETRIC FUNCTIONS

Russian	English	Russian	English	Russian	English
sin	sin	sh	sinh	arc sh	$\sinh^{-1}$
cos	cos	ch	cosh	arc ch	$\cosh^{-1}$
tg	tan	th	tanh	arc th	$\tanh^{-1}$
ctg	cot	cth	coth	arc cth	$\coth^{-1}$
sec	sec	sch	sech	arc sch	sech^{-1}
cosec	csc	csch	csch	arc csch	csch^{-1}

Russian	English
rot	curl
lg	log

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TEMPERATURE ERRORS OF RADIOSONDE RKZ-2 AND ITS WORKING PROCEDURE

O. V. Marfenko

In order to solve a number of procedural problems which originate during the operation of a radiosonde, it is not sufficient to know the value of its resultant error for the element being measured. The components of this error have different magnitudes and origins, which make it necessary to have different methods of determining them and to be able to take them into account under conditions of standard observations at aerological stations. A study of the error in measuring temperature with radiosonde RKZ-2 was conducted in 1967-1968 in order to solve this problem.

The error in temperature measurement by radiosonde type RKZ consists of the error caused by the thermistor and the error caused by the radio component. We studied the main error contributed by the radio component; by this error we mean the reproducibility of the radio component readings under normal conditions (room temperature, ground pressure, nominal supply conditions: $U_{н_1}$ = 2.4 V, U_a = 195 V, $U_{н_2}$ = 6.1 V, respectively), and the additional error which originates during the deviation of the supply conditions of the radio component up to the maximum permissible values. The change in the radiosonde readings through time was studied in order to determine the useful life of the radiosonde.

We found the main error of the radio component by comparing data from repeated tests of radio components at close intervals and with constant supply voltages (nominal and deviating from nominal by 8-10%). The test was made with a set of monitoring and measuring equipment (KIPAS-1).

Table 1 gives the mean absolute $\left(\overline{|\Delta t|} = \frac{\sum_{i=1}^{n} |\Delta t_i|}{n}\right)$ and mean arithmetic $\left(\overline{\Delta t} = \frac{\sum_{i=1}^{n} \Delta t_i}{n}\right)$ values of the differences in repeated tests of 20 radio components of radiosonde RKZ-2 at 15 testing levels, expressed in degrees. The input data in Table 1 include the values of the resistances measured by the radio component corresponding to the testing stages and the approximate values of the temperature corresponding to the indicated values of the resistance of thermistor MMT-1. The data were obtained with the nominal supply conditions. The fact that the mean arithmetic values of the differences are equal to zero indicates that the series of measurements is sufficient for obtaining reliable data on the value of the error. The rms value of the main error in measuring the temperature, calculated using the above data, is less than 0°, and that caused by the radio component - not greater than 0.1°. A higher temperature is measured with a greater error, reaching 0.6-0.7° at a temperature of 20-40°C.

It turned out that the determining component of the main error of the radio component is that which depends on the sensitivity of the radiosonde. The error in the temperature measurement, which depends on the sensitivity of the radiosonde, is determined by the following value in the limiting case

$$\Delta y = \frac{\Delta F_t F_{on} + \Delta F_{on} F_t}{F_{on}^2},$$

where $\Delta F_t = \Delta F_{on} = 1$ Hz is the discreteness of the frequency measurement, $F_{on} = 2000$ Hz, F_t varies within 50-1950 Hz.

The values of the errors corresponding to the values of Δy for different temperature ranges are given in the last line of Table 1.

Table 1. Mean differences in readings of radio components of RKZ-2 taken at close intervals (degrees).

KEY: (1) kilohms. (2) Number of cases. (3) degrees. (4) No. of testing stage.

	(4) № ступени поверки						
	1	2	3	4	5	6	7
R, кОм (1)	1,3	5,6	7,6	11	15	20	36
t °C	50	40	25	15	5	15	23
Δt	0,03	0,1	0,02	0,01	0,02	0,05	0,03
Δt	0,11	0,21	0,23	0,19	0,12	0,12	0,08
(2) Число случаев	10	20	20	20	20	20	20
Δt [illegible] 0,0005 (3)	0,37	0,26	0,20	0,15	0,10	0,10	0,09

(cont'd)

	8	9	10	11	12	13	14	15
R, кОм (1)	47	62	82	110	150	200	270	360
t °C	30	35	44	50	55	65	70	75
Δt	0,02	0,02	0,02	0,02	0,01	0,01	0,01	0,05
Δt	0,09	0,08	0,04	0,02	0,03	0,02	0,03	0,01
(2) Число случаев	20	20	20	20	20	20	20	20
Δt [illegible] 0,0005 (3)	0,08	0,07	0,08	0,09	0,10	0,11	0,12	0,14

They turned out to be approximately equal to the values of the main error. This is important when solving the problem of the decrease in the frequency range for the transmission of information on meteorological data, i.e., of the decrease in the radiosonde's sensitivity: the decrease in sensitivity increases the random error introduced into the measurement of the meteorological element by the radio component almost to the same extent.

The dependence of the output data of a radio component carrying information about meteorological elements on the voltage of the supply battery causes a significant error in the measurement of air temperature and humidity by radiosonde RKZ.

Studies which were conducted earlier [1] showed that this error is systematic for a particular radiosonde: the deviation of the supply voltage from the nominal value, with a constant value and sign, causes a constant error in the measurement of the meteorological element. The value of the error for this voltage deviation varies from radiosonde to radiosonde according to the normal law

of distribution, and it is determined by the construction of the radio component and the quality of its adjustment. The sign of the error is determined by the sign of the voltage deviation: an increase in the filament voltage of 2.4 V or a decrease in the anode voltage results in a decrease in the true air temperature, and vice versa. The filament voltage of 2.4 V has the greatest effect on the change in the readings of the radio component. The following mean values of the errors in measuring the temperature were obtained during changes in the supply conditions of the radio component up to the maximum permissible values.

$$\begin{array}{lll} \text{In the regime} & \left.\begin{array}{l} U_a = 212\ в, \\ U_a = 178\ в, \\ U_a = 212\ в, \\ U_a = 178\ в, \end{array}\right\}^{(1)} \begin{array}{l} U_{н_1} = 2{,}65\ в \\ U_{н_1} = 2{,}15\ в \\ U_{н_1} = 2{,}15\ в \\ U_{н_1} = 2{,}65\ в \end{array}\left.\right\}^{(1)} & \begin{array}{r} +0{,}25^\circ; \\ 0{,}20^\circ; \\ -0{,}40^\circ; \\ +0{,}30^\circ. \end{array} \\ \text{» »} & & \\ \text{» »} & & \\ \text{» »} & & \end{array}$$

KEY: (1) V.

It has been pointed out that for a given batch of radiosondes, the value of the mean error under given supply conditions, expressed in degrees, is the same for all the testing stages of the radiosondes, i.e., for the entire measured temperature range. From the standpoint of the effect on the precision of the radiosonde, a decrease in the supply voltage, especially the 2.4 V filament voltage, turns out to be the most dangerous.

Figures 1 and 2 give the discharge characteristics of battery 200 PMKhM-2ch for the anode and 2.4 V filament voltages. These curves were obtained in a space chamber on a load equivalent to a radio component after preliminarily charging the battery to the minimum working voltages ($U_{н_1}$ = 2.15 V, $U_{н_2}$ = 5.5 V, U_a = 178 V) and discharging it at ground pressure for 10 minutes at a temperature of +25°C and 5 minutes at a temperature of -40°C. Table 2 gives the working conditions of the battery after the 15th minute, which was considered to be the beginning of the useful operation of the battery

This procedure of preparing the batteries before beginning the tests corresponds to their operating conditions.

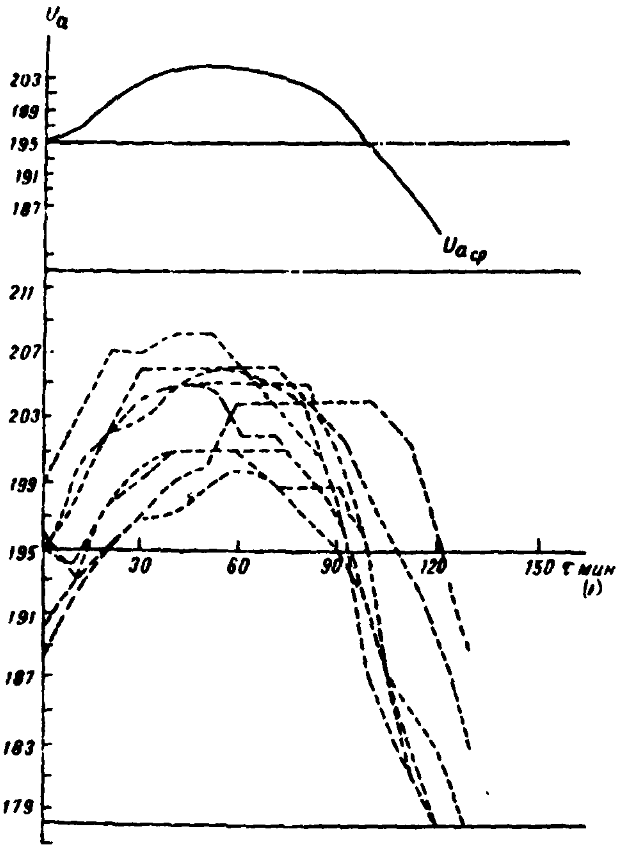

Fig. 1. Discharge characteristics of anode section of battery 200PMKhM-2ch.

KEY: (1) min.

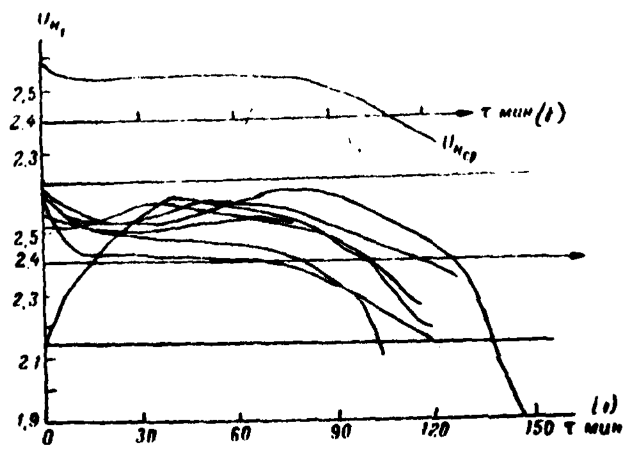

Fig. 2. Discharge characteristics of filament section of battery 200PMKhM-2ch.

KEY: (1) min.

Table 2. Conditions of discharge of battery 200PMKhM-2ch.
KEY: (1) Time, min. (2) mbar.

	(1) Время, мин							
	0	15	30	45	60	90	105	120
P мб (2)	970	700	160	250	130	25	5	5
t C	10	11	17	50	52	52	-52	-52

The lower part of Figures 1 and 2 gives the discharge curves of individual batteries from separate batches, and the upper part - the mean curves for batteries from 14 different batches. It is characteristic for the filament section of the battery to rapidly reach the maximum voltage for this battery, to preserve it for approximately 90 minutes, and then for it to quickly drop. The anode section is characterized by rapidly reaching the minimum voltage during charging, a gradual build-up for 50-60 minutes to the maximum value, and then a gradual drop for 30-35 minutes. Only after this does a rapid drop occur. The rapid build-up of voltage during the first minutes of the battery's useful operation is the result of the features of the experiment. Actually, during charging, the anode section reached the minimum working voltage much sooner than the filament section, and it was cut off. During the first minutes of discharge in the working mode, the anode section was essentially discharged.

The findings give us grounds for considering the supply conditions of the radio component to be sufficiently stable during individual sounding, and the errors in measuring a meteorological element under conditions of atmospheric sounding, which originate when the supply conditions deviate from the nominal conditions - to be systematic.

Attention is drawn to the fact that the nominal supply conditions of radio component RKZ do not correspond to the mean voltages supplied by batteries 200PMKhM-2ch: $U_{н1}$ = 2.5, $U_{а}$ = 200 V. Data indicating that the mean voltages supplied by batteries 200PMKhM-2ch are generally

higher than the nominal values under actual sounding conditions are confirmed by the values of the radiosonde's reference frequencies in flight and the values of the variations during the test check of the radio components at aerological stations.

It is important to know the stability of the radiosonde's calibration data through time in order to determine the working procedure. Here it is important to know not only the value, but the nature of the change in the radiosonde's readings through time. Thus, if the calibration curve through time is shifted parallel to the original plant curve, it is sufficient to take a control reading in order to determine the correction to the calibration data, which will be constant for the entire range of the measured element.

Table 3. Change (degrees) in readings of radio components RKZ-2 through time.

KEY: (1) Stage. (2) Storage time, months. (3) Description of error. (4) Mean arithmetic. (5) Mean absolute.

(2) Длительность хранения, мес.	(3) Характеристика ошибки	(1) Ступени 2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	(4) Средняя арифметическая	0,48	0,42	0,20	0,14	0,14	0,02	0,04	-0,02	0,08	0,12	0,20	-0,06	0,00	-0,04
	(5) Средняя абсолютная	0,46	0,46	0,28	0,12	0,20	0,06	0,12	0,18	0,14	0,18	0,16	0,07	0,20	0,02
12	(4) Средняя арифметическая	0,14	0,18	0,12	0,12	0,15	0,13	0,09	0,12	0,22	0,18	0,13	0,16	-0,19	0,13
	(5) Средняя абсолютная	0,37	0,28	0,31	0,29	0,38	0,31	0,32	0,31	0,37	0,35	0,38	0,32	0,30	0,29
21	(4) Средняя арифметическая	0,22	0,28	0,00	0,05	0,05	0,12	0,13	0,15	0,08	0,13	0,20	0,20	0,22	0,18
	(5) Средняя абсолютная	0,43	0,29	0,30	0,25	0,32	0,29	0,28	0,25	0,27	0,25	0,15	0,18	0,21	0,25
30	(4) Средняя арифметическая	0,17	0,11	0,26	0,27	0,31	-0,23	0,21	0,28	0,38	0,31	0,25	-0,32	0,27	-0,28
	(5) Средняя абсолютная	0,37	0,21	0,25	0,23	0,26	0,21	0,21	0,21	0,22	0,27	0,23	0,24	0,25	0,29
33	(4) Средняя арифметическая	0,0	0,03	-0,13	-0,16	0,15	-0,04	0,02	0,06	0,09	0,03	0,03	0,09	0,05	-0,02
	(5) Средняя абсолютная	0,27	0,25	0,21	0,16	0,17	0,14	0,14	0,17	0,22	0,19	0,21	0,20	0,18	0,18

(cont'd)

The results of studying the change in the radio component readings of radiosonde RKZ-2 through time are given in Table 3. The

observations were made on 15 radio components taken from different batches. Table 3 gives the mean arithmetic and mean absolute differences in the readings of the radio components during plant calibration and after 1, 12, 24, 30 and 33 months. The findings do not indicate the presence of any regular variations in the radio component readings through time. Nor was an increase in the absolute values of the differences through time observed. The mean absolute value of the deviation in the 5th and higher stages does not exceed 0.4°. The variations in the readings of individual radio components are different: in some, the new calibration curve is shifted parallel to the plant curve, while in others, it changed (the sensitivity changed), and sometimes the points of the test check were randomly dispersed relative to the plant curve. This nature of the differences in the radio component readings makes it possible to confirm that they result from errors in either the plant or the test calibration using the KIPAS-1. Deterioration of the calibration data of the radiosonde does not occur, at least for three years.

The results of studying the errors of RKZ radiosondes indicate the need for considering two aspects of the question of a radiosonde's precision. The first aspect is the precision of a given type of radiosonde, the value of which is necessary in order to estimate the precision of the aerological information. This precision is determined statistically according to test data on a set of this tvpe of radiosondes under laboratory or flight conditions. The second aspect is whether the precision of a particular radiosonde meets the precision requirements imposed on this type of radiosonde, i.e., determining the radiosonde's suitability for sounding.

Statistical methods of determining even random errors are not very well-suited for conditions of plant production and operation at aerological stations. Knowing the statistical characteristics of the random errors of a given type of radiosonde, it is more expedient to establish criteria for the permissible value of the error of a particular radiosonde. We feel that it is advisable to take the value 2σ, for which the confidence probability is equal to 95%, as the criterion for estimating the suitability of a particular

radiosonde for sounding. The value of σ is determined from the findings of the study of a set of radiosondes. Here it is obligatory to make an individual determination and estimation of the random and systematic errors for a particular radiosonde.

The total rms error introduced by a radio component of radiosonde RKZ-2, which characterizes the precision of this radiosonde, is equal to

$$\sigma_p = \sqrt{\sigma_1^2 + \sigma_2^2 + \sigma_3^2} = \sqrt{0{,}1^2 + 0{,}15^2 + 0{,}15^2} = 0{,}23 .$$

Here σ_1 is the rms value of the main random error introduced by the radio component; σ_2 is the rms value of the error introduced by the radio component with a value of the anode voltage of 200 V, and of the filament voltage - 2.5 V; σ_3 is the rms value of the error contributed by the procedure for testing the radio component. The total random error in measuring temperature by radiosonde type RKZ-2 is equal to the geometric sum of the errors of the radio component and the errors of the thermistor:

$$\sigma_{\text{сум}} = \sqrt{\sigma_{p}^2 + \sigma^2} = \sqrt{0{,}23^2 + 0{,}4^2} = 0{,}46 .$$

This value of the error is also confirmed by the connected outputs of the radiosonde [2]. We obtained data on the errors of the thermistor by analyzing the results of studying the stability of thermistors MMT-1; this study was conducted at the Testing Office of the TsAO [Central Aerological Observatory] in 1961. It was found that on the average, because of changes in the calibration data of the thermistor over 3-12 months, the radiosonde lowers the air temperature by 0.15-0.25°C with a deviation of ±0.2° from the mean in individual testing stages. Therefore, the systematic component of the value of the change in the calibration data of a thermistor through time is approximately equal to the random error of the thermistor, which makes it impossible to determine from a single test reading. The mean absolute value of the change in the calibration data of the thermistor according to the data of test checks at aerological stations is somewhat higher than according to the data of special laboratory studies, and it is equal to 0.4°. In all probability, this is explained by the inaccuracy

of the procedure for test checking a thermistor in a ventilated booth.

When estimating suitability from the precision characteristics of each individual radiosonde, it is necessary, as we already indicated, to separately estimate the random error introduced by the radio component and the systematic error which originates when the supply conditions are varied up to the maximum permissible values.

The random error is estimated from the difference in two successive calibrations of a radio component with constant supply conditions. The value of 2σ, which is a cause for condemning a radio component when it is exceeded, is normalized separately for each test stage. According to our data, it is equal to 0.8° in the second stage, 0.25° in the 3rd stage, 0.2° in the 4th stage, 0.1° in the 5th-13th stages, and 0.15° in the 14th and 15th stages.

It is expedient to estimate the error introduced by radio component RKZ during a change in the supply voltages according to data of test readings in the range in which the random error of the radio component is small. In this case, it is not necessary to have a large number of measurements. It is sufficient to have two test readings, e.g., at the 6th (20 kilohms) and 13th (200 kilohms) test points in order to keep the maximum error from exceeding 0.2° on the average. It suffices to make the check in two of the most unfavorable sets of conditions: 1) U_a = 212 V, U_{H} = 2.15 V (+A, -H); 2) U_a = 178 V, U_{H} = 2.65 V (-A, +H). The criterion for rejecting a radio component according to the value of the difference in the radio component readings under the nominal conditions and in the regimes +A-H or -A+H in the 6th or 13th stages is the sum of twice the rms value of the main error and twice the rms value of the error of radiosonde RKZ-2 under the indicated supply conditions. This value is equal to 1.2°C, according to our findings.

For conditions of aerological stations, the criterion should be somewhat higher when considering the additional error introduced

by monitoring and measuring equipment of a lower class of precision than the factory equipment.

Furthermore, the findings make it possible to bring out the problem of the change in the nominal supply regime of the radiosonde and the increase in its service life for sounding for up to at least three years. At present, it is not advisable to introduce corrections into the calibration data of a radiosonde from data of a control test at aerological stations. The introduction of corrections which consider the value of the voltages supplied by battery 200PMKhM-2ch, with which the radiosonde is sent up, makes it possible to somewhat decrease the systematic error in temperature measurement during individual sounding situations. However, we were unable to obtain more precise sounding results by processing connected outputs of radiosondes RKZ-2 with the introduction of corrections in the calibration data of the radio components obtained from the findings of test readings in the 20 and 200 kilohm stages during supply from a battery. Nor did the precision increase when corrections were introduced into the calibration data of the thermistors obtained by comparing the temperature readings of a radiosonde and an aspiration psychrometer in a ventilated booth.

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Summary

The results of the investigation of the radiosonde PKZ-2 type temperature errors are described in this paper. Some methods of the radiosonde verification are given.